Site Identification and Recommendations for Control of *Phragmites australis* on Colonial National Historic Park, Virginia, USA

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Introduction

Phragmites australis Trin. is considered an invasive plant species that will replace wetland vegetation in disturbed marsh habitat in Virginia (Virginia Heritage Program 1992), particularly those caused by human disturbances (e.g. road construction, boat and human access to waterways, power- and pipeline construction and maintenance) and natural disasters (e.g. shoreline erosion, hurricanes, and northeasters). Although a native species, once *P. australis* has a foothold in a marsh it has the capability of rapidly invading and out competing the usual dominant wetland species found in Colonial National Historical Park (COLO) marshes, such as *Spartina alterniflora* (smooth cordgrass), *S. cynosuroidies* (tall cordgrass), and *S. patens* (salt meadow hay). The replacement of the *Spartinas* by *P. australis* leads to loss of both habitat and species diversity (Silberhorn 1999). To that end, resource managers have begun to examine "eradication" methods to minimize the invasion of *P. australis.*

COLO has identified 17 wetland sites in the park that have been invaded by nearly monotypic stands of *P. australis*. Virginia Institute of Marine Science (VIMS) wetland personnel visited each of these sites and seven others not previously identified and, working with COLO Natural Resource Manager, have prepared a management plan that is site specific, along with a generic monitoring protocol that can be easily implemented by park staff. This monitoring protocol includes methods for measuring the success of the treatment and a threshold to determine the need for additional control.

The management plan is based on current local research as well as the most recent scientific literature. VIMS personnel will work with the COLO contractor responsible for implementing the control program to assure compliance with the plan.

Rational for Development

Although *P. australis* is considered to be an invasive wetland species in North America, it can play a positive role in wetland habitat management. Waterfowl species benefit from *P. australis* when the plant stands are interspersed with open water or with other vegetation. *P. australis* stems provide cover and nesting habitat, and rhizomes provide a food source for waterbirds and small mammals. Its dense root systems have also been used to strengthen dikes and roads and reduce beach erosion.

The key may lie in integrated management of *P. australis*. The first important step is deciding what level of control is needed for a stand. In some cases, although a monoculture of *P. australis* exists, the best decision may be not to apply any control methods to the area. Yet, if it is decided that *P. australis* control is part of an overall management plan, careful steps should be taken to select a control method.

When it is decided that action must be taken to decrease the amount of *P. australis* in an area, having a plan and clear objectives is important. It is also crucial that the management plan include a long term monitoring program to insure the desired results are maintained. It was once thought that a 5-year monitoring plan was sufficient. However, monitoring for a longer time period is more likely the case (Mitsch and Wilson 1996, Havens et al. 1997).

Summary of Methods for Controlling *Phragmites australis*

Following is a list of methods that have been used in controlling *P. australis* (modified

from Norris et al. 2001). While not all are pertinent to the COLO area, they have been included for completeness.

I. Chemical Control

Spraying

Chemical spraying is one of the most popular choices of habitat managers. Translocation of the chemical to the root system can successfully kill the entire plant. The challenge lies in correctly timing the spraying application. Chemical spraying is most effective if applied in the fall, when a majority of the plants are in full bloom and leaves are fully open. During this time, the plant is actively moving stored energy from leaves to the complex rhizome system. Taking advantage of this energy shift insures the highest opportunity that the selected chemical will reach the rhizomes. In addition, in temperate zones, more desirable species such *Spartina alterniflora* and *Spartina cynosuroides* may have already begun to senesce reducing the potential for impacts to non-targeted species.

Glyphosate (N-(phosphonomethyl) glycine), sold under the trade name Rodeo 7 or Rodeo Pro 7 by Monsanto, is the most common herbicide used to control *P. australis*. It should be noted, however, that using a high concentration of chemical designed to translocate in the rhizomes (such as glyphosate), can result in top kill of the plant before the herbicide can be translocated properly, thus decreasing the effectiveness of the treatment. It is noted that split applications of glyphosate (at 1/2 dosages) can work better that a single, full strength application. The second dosage should be applied 15-30 days after the first (Cross and Fleming 1989).

The dense nature of *P. australis* may prevent complete chemical coverage and result in uneven stages of growth. So, repeat treatments may be necessary to maintain control (Brooker 1976). Seasonal burning, used in combination with spraying the vegetation, has been shown effective in reducing the above ground biomass thus increasing the opportunity for complete coverage when spraying (Cross and Fleming 1989).

Spraying comes in two forms: aerial and hand. Aerial spraying is done by fixed wing plane or helicopter and has been used successfully in large wetland areas greater than 10 acres. However, aerial spraying is not species selective and native species, such as *Spartina* and *Typha* are also affected. For smaller areas (<10acres) or areas with sensitive habitat and/or biota, hand spraying is recommended (see also “Wicking” and “Removal by Hand” below for alternative small area removal methods).

Wicking

Wipe-on herbicide application, or wicking, has been investigated as a more environmentally acceptable alternative to spray applications. The method utilizes canvas-covered, Speidel 7 applicators attached to a boom on each side of the boat or low ground pressure application equipment. The chemical saturates the canvas strips and is only applied to the plants that come in direct contact with the fabric. Chemical application through wicking allows for the targeting of *P. australis* without affecting the other, often shorter, plant species present in the treatment area. This method can be useful in areas where complete eradication of all vegetation is not desired.

However, care should be taken when using wicking equipment. The equipment can bend and break the plant, reducing the opportunity the chemical will reach the rhizomes and thus

reducing the effectiveness of the treatment (Kay 1995). In addition to breaking plant stalks during application, the application boom also may cause much of the taller stalks to bend over and cover the shorter *P. australis* plants. This can effectively shield the shorter plants from the chemical, therefore reducing the rate of contact with the desired vegetation. In heavy weed stands, a double application in opposite directions may improve the results (Monsanto 1995). Yet, double applications will increase the treatment cost, effort and likelihood of stem breakage.

Sulfide Treatments

Studies have shown that sulfides react with salinity to greatly impact *P. australis* communities. Many of the die-back symptoms associated with field sites, namely stunted adventitious roots and laterals, bud death, callus blockages of the gas-pathways, and vascular blockages, were particularly acute at higher concentrations of acetic acid and sulfides (Armstrong et al. 1996). It has also been shown that an increase in sulfide in the rhizosphere reduces the ability of *P. australis* to take up nutrients relative to species such as *Spartina alterniflora* that are better-adapted to sulfuric soil conditions, thus restricting the distribution of *P. australis* in tidal saltmarshes (Chambers 1998). Sulfide treatments are not a viable option for COLO.

II. Mechanical Control

Water Management

Regulating the water level within the treatment area can be used to controlling *P. australis*. *Phragmites australis* roots require little oxygen and have well-developed mechanisms of flood tolerance. Therefore, flooding an established colony of *P. australis* may not be effective (Gries et al. 1990). However, if a water level greater than 30 cm is maintained, colonies will not expand and further increasing water levels can easily kills seedlings.

Tidal flushing can be effective in preventing *P. australis* from becoming established. But, a coastal location is required and increasing the salinity is more likely to hurt competing plants and the freshwater biota than control *P. australis* to the desired levels (Cross and Fleming 1989). Due to the dense nature of root and rhizome systems, wave action has been shown to have no effect on established stands of *P. australis*. In fact, the presence of *P. australis* actually reduced the amount of erosion normally caused by repeated wave action. Water management is not a viable option for COLO.

Disking

Disking is more effective than plowing because the chopped rhizome pieces that result are often too small to be viable. The most effective time for cutting rhizomes is late in the growing season. In dry areas, the rhizome fragments may remain above ground to dry out or freeze. Disking in the summer or fall has shown a reduction in stem density during the next growing season. But, disking in late winter to mid-summer has actually stimulated bud production and resulted in *P. australis* stands with greater stem density (Cross and Fleming 1989). Disking is not a viable option for COLO.

Bulldozing

Bulldozing can be destructive to *P. australis* under certain conditions. Removal of vegetation can expose rhizome fragments to killing frosts, or fragments can dry out in non-

flooded areas. However, this level of disturbance can also provide ideal growing conditions for *P. australis* (Cross and Fleming 1989).

Dredging

Complete removal of *P. australis* through dredging can be difficult and destructive to the surrounding area. Rhizomes can reach depths of 2 m or more (Haslam 1970). Horizontal rhizomes must be removed and the area must remain deeply flooded (more than 1.5 m) following dredging or regrowth will almost certainly occur (Cross and Fleming 1989). Dredging is not a viable option for COLO.

Seasonal Mowing

Mowing a stand of *P. australis* has been shown to reduce biomass and increase the available sunlight to competing plant species within the stand. Spring mowing has produced shorter, but denser, *P. australis* stands within the same growing season. Yet, mowing for three consecutive summers in Canada resulted in a reduction of *P. australis* and a replacement of a short grass-sedge-sowthistle meadow (Cross and Fleming 1989). Mowing is not a viable option for COLO.

Cutting

Reducing the above ground biomass through labor-intensive cutting has produced mixed results. In one study, fall cutting did not increase species richness (Thompson and Shay 1989). Yet, hand-cutting 30-40 cm below the water level in June resulted in total eradication of the *P. australis* stand (Kay 1995). The level of the cut must be made below water level and a high water level maintained, to allow the shoot bases to become flooded with water from the top. This has been shown to result in the plant rotting beneath the water, especially when the cut is applied twice during one growing season (Husak 1978).

Short-term results were also obtained by cutting the vegetation at the onset of flowering. However, within two years, no significant differences were detected in the above ground biomass between treatment and control plots (Husak 1978). Cutting is not a viable option for COLO.

Plastic Barriers

Applying large plastic sheets to a treatment area can be an effective, non-herbicide option for eradicating *P. australis*. The site should first be mowed or burned to reduce the height of above ground biomass. Large sheets of 6-mm plastic can then be applied and held in place with stakes, sandbags or chains. As the under plastic temperatures increase, complete surface kill can be achieved in only 3-4 days. An increased application time could eventually kill the rhizomes as their energy storage is depleted and soil temperatures remain high (Boone et al. 1988). Using a clear plastic has been shown effective and it is suggested that using a black plastic could further increase under plastic temperatures.

However, large plastic sheets can be difficult to manage and hold in place, particularly in tidal marshes. Extended time in the sun can also increase the possibility of the plastic to deteriorate into hundreds of tiny pieces, making clean up difficult. Small animals located in the wetland area may be drawn to the warm temperatures located under the plastic sheeting and can potentially tear the material. The sharp tips of *P. australis* rhizomes have also been known to

easily penetrate plastic sheeting. Plastic Barriers are not a viable option for COLO.

Perimeter Ditching

During construction of a new tidal wetland site, ditching around the perimeter may be effective in preventing the spread of rhizomes (Havens et al. 1997). While designing a new tidal wetland site, special attention should be given to elevation. In polyhaline areas much of the potential for *P. australis* invasion can be eliminated by concentrating restoration efforts to below mean high water (Priest 1989). The project should also include additional steps to eliminate areas available for *P. australis* development. These steps include planting a high density of vegetation, using mature scrub/shrub species and plantings along the upland berm. Perimeter ditching is not a viable option for COLO.

Burning

Habitat managers have traditionally used controlled burning as a quick and efficient method for removing above ground biomass and increasing soil nutrients. In fact, it is commonly used in combination with other *P. australis* control methods such as chemical spraying. However, new discussions are taking place concerning annual burns to control *P. australis* on wetland properties. Most professionals agree that removing the above ground biomass does indeed allow more sunlight to reach the soil surface and thus increases the opportunity for more desirable plants to sprout and grow. However, it is suggested that removing the above ground biomass on an annual basis may not allow the build up of nutrients to be returned to the wetland soil. In addition, the bare soil following a burn often provides prime disturbed conditions for the establishment of *P. australis*.

Shading

Seedlings of *P. australis* are susceptible to shading (Haslam 1971, Kudo and Ito 1988, Ostendorp 1989). Shading by shrubs and trees can reduce the density, height, and the proportion of flowering shoots, and can increase the number of dead tips (Lambert 1946, Kassas 1952, Haslam 1971). In created or restored areas, simply allowing scrub/shrub vegetation to mature can reduce *P. australis* to a minor component of the vegetative community (Havens et al. 2001). Shading is not a viable option for COLO.

Removal by Hand

Perhaps the most laborious method, but the lest environmentally damaging, is to physically pull the *P. australis* plant from the ground. This method works well for very small populations but may not be practical for areas with an invasion that covers areas of greater than 0.25 acres. Care must be taken to assure that all root and rhizome material are removed with the plant.

III. Biological Control

Classical biological weed control is the introduction of host specific natural enemies (usually insects, less often pathogens) from the native range of the plant. Over 100 insect species are known to attack *P. australis* in Europe and about 50% of these are *P. australis* specialists. This provides ample opportunity to assess their potential as biological control agents

(Blossey 2000).

The most promising potential biological control agents are rhizome and shoot mining moths and flies. The highest priority for investigation lies in the rhizome feeding insects, and is followed by the stem and leaf feeders. If an insect is discovered to destroy the rhizomes, the entire *P. australis* plant will be killed. When the desired control level is met, a controlled burn of the area destroys the insects along with the above ground biomass. Some of the insect species being investigated have recently been introduced to North America and the destructive potential of these species on *P. australis* is very promising (Blossey 2000). Biological control is not a viable option for COLO

Results and Management Recommendations

A total of 29 sites were visited. Three sites previously identified as dominated by *P. australis* had no *P. australis* during this study and, therefore, have been removed from the list. In most cases large, dense, monotypic stands were found. However, due to the sensitivity of the inclusive and adjacent habitats, aerial spraying has not been recommended for any of the sites. This should not be taken as an attempt to rule out aerial spraying, but to be a strong caution that its use may cause unnecessary environmental damage. A description of control methods recommended for each site (such as hand spaying or wicking) can be found in the follow the descriptions provided in the above section "Summary of Methods for Controlling *Phragmites australis"*. An overview of site conditions and recommendations for all sites is given in Table 1. Figures for each site are presented at end of list. The term "clonal" is used throughout the descriptions to describe *P. australis* populations that have formed large, round, flowering colonies of monotypic stands. Access was defined as 1) easy (vehicle access immediately adjacent to site), 2) moderate (vehicle access to within 300 to 500 ft. of site) or 3) difficult (no vehicle access within >600 ft. or boat access necessary). Several large sites have easy access to those populations adjacent to the road, but also more difficult access to interior populations or have populations on marsh islands. Suggested treatments are given in order (priority) of recommended method.

Site 1
Description: Large dense patch in non-tidal upper marsh zone of tidal creek. Although dominated by *Phragmites australis*, area contains many other beneficial wetland plant species.
Access: moderate to difficult
Recommendations: Hand spray with wicking in high diversity areas and transition zones. One-time burning would be helpful to remove *P. australis* debris, but care must be taken to avoid species rich and upland fringe areas.

Site 2
Description: Small stand of monotypic *P. australis* population with a high potential to spread in non-tidal wetland. Interspersed with diverse native flora on edges.
Access: difficult
Recommendations: Hand spray with wicking in high diversity areas and transition zones. One-time burning would be helpful to remove *P. australis* debris, but care must be taken to avoid species rich and upland fringe areas.

Site 3
Description: A small clonal population on the high marsh edge and extending into a tidal *Spartina alterniflora* marsh. Has high potential for spreading.
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. One-time burning would be helpful to remove *P. australis* debris as tidal flushing on the site is limited.

Site 4
Description: A continuous, thin (<10m) strip of *P. australis* growing in the high marsh zone of the York river behind an eroding *Spartina patens* marsh. There is a small riprap structure in front of the marsh to abate erosion. A large portion of the *P. australis* population is mixed with other marsh species such as bayberry shrubs, Virginia cedars, and saltbushes, and bull-briars.
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 5
Description: Moderate size population of *P. australis* in tidal high marsh zone. Intermixed with *Spartina cynosuroides* in the high marsh and *Spartina alterniflora* in the low marsh zone.
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 6
Description: Located across the road from site 5, this site is heavily dominated by *P. australis*. Tidal influence through culvert under road, but diminished to near imperceptibility.
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. One-time burning would be helpful to remove *P. australis* debris as tidal flushing on the site is limited.

Site 7
Description: Low density, however fairly wide spread throughout the high marsh. Continuous patch with potential to rapidly expand. Located on the high marsh landward of *Spartina alterniflora* marsh. Intermixed with bayberry, Virginia cedars, and saltbushes.
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater

tidal flushing of the *P. australis* debris.

Site 8
Description: Dense clonal population in small tidal high marsh cove. Surrounded by bayberry, Virginia cedars, and saltbushes on upland and *Spartina alterniflora* on low marsh transition zones.
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 9
Description: Moderate size clonal population located in the high marsh tidal zone with *Spartina alterniflora* dominant in low marsh and bayberry and American holly in the upper transitional marsh zone.
Access: moderate
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 10
Description: High diversity non-tidal marsh. *P. australis* population fairly well defined in monotypic patch.
Access: moderate
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. One-time burn is also recommended.

Site 11
Description: Very large, dense, tidal population. Many clonal populations, however there are many mixed populations as well.
Access: easy to difficult – most of shoreline easy, but one small island and northeast corner clonal population will require a boat
Recommendations: Aerial spray may be a possibility, however, due to large number of sensitive habitats and species, hand spraying needs to be considered. One-time burn is also recommended.

Site 12
Description: Moderate size clonal population on point tidal marsh. Has eroding front edge. One lone cypress tree found in marsh.
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater

tidal flushing of the *P. australis* debris.

Site 13
Description: Moderate size clonal population with several species of trees scattered throughout the high marsh zone (tidal).
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 14
Description: This is the largest population found during the study. It consists of a very large mix of clonal and mixed communities. Runs from College Creek bridge to northwest bank, crosses over Rt. 199 to southside of the road. Tidal.
Access: easy
Recommendations: Aerial spray may be a possibility, however, due to large number of sensitive habitats and species, hand spraying needs to be considered. One-time burn is also recommended. Re-seeding with *Spartina alterniflora* and *S. cynosuroides* should be given serious consideration.

Site 15
Description: Dense, monotypic population in embayment high marsh (tidal).
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 16
Description: No *P. australis* was not found in the designated area. However, a large clonal patch was found on the northwest side of the Powhatan Bridge on both COLO and adjacent property.
Access: difficult
Recommendations: Seek permission of adjacent property owners to control patch on northwest corner. Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 17
Description: Several large clonal populations scattered throughout the area. Most are only accessible by boat. Very high potential for spreading into adjacent areas.
Access: difficult
Recommendations: Hand spay central portion of population and hand wick transitional edges

where *P. australis* is mixed with other species. Burning should be considered for these areas. If burning proves to be to difficult, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 18
Description: Two large clonal populations within a *Spartina alterniflora* marsh.
Access: easy to moderate (due to distance one population extends into marsh being >300ft.)
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 19 (no pictures)
Description: Small population along fringe of tidal *Spartina cynosuroides* marsh.
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 20
Description: Moderate clonal population bordering loop road. Upland populated by loblolly pine and low marsh by mixed brackish marsh species. Very high potential for spread.
Access: easy
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 21 (no picture)
Description: Fairly large clonal population within tidal *Spartina cynosuroides* marsh.
Access: difficult
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 22
Description: Small population approx. 50ft. off loop road in cove of tidal *Spartina cynosuroides* marsh.
Access: easy to moderate
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater

tidal flushing of the *P. australis* debris.

Site 23 (no picture)
Description: Clonal population within tidal *Spartina cynosuroides* marsh. Larger than reported.
Access: difficult
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 24
Description: Several large and one small clonal populations located approx. 1/2mile through *Spartina alterniflora* marsh and approx. ½ mile apart.
Access: difficult
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 25 (No pictures)
Description: Small population (~0.5 acres) fringes loblolly pine tree grove. Tidal.
Access: moderate to difficult
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater tidal flushing of the *P. australis* debris.

Site 26 (No pictures)
Description: Crescent shaped patch and another long patch along loblolly pine interfluvial. Both total approx. 1 acre in size.
Access: moderate to difficult
Recommendations: Hand spay central portion of population and hand wick transitional edges where *P. australis* is mixed with other species. No burning is recommended for this site, however, hand cutting the standing dead material over the winter months will allow for greater t

Monitoring

Monitoring will need to be a multi-year process and will begin the first growing season after control methods have been applied. A major effort for documenting the success of the treatment is outlined in Year 2.

Year 1 (first growing season after treatment):

Spring - Walk each site and search for new (or returning) *P. australis* shoots and for areas that may have been accidentally missed on first treatment. If areas are small (<100 square feet) careful removal by hand is recommended. If larger, a second chemical treatment in the fall may be necessary. Chemical treatment in spring is not recommended.

Fall – Re-check spring sites that showed re-grown of P. australis. Use chemical treatment if necessary.

Year 2:

Repeat procedure for year one on all sites that had to be retreated. Document with photographs. Make quick walkthrough and photographic record of sites that were successfully treated. A more rigorous monitoring program is also recommended:

1. Choose ten or more sites randomly from the list. In each of those sites establish ten random 1m x 1m quadrat
2. estimate cover and count density of each species found in the quadrats
3. calculate species Importance Values (IV) of plant species using the following formulas (see Perry and Hershner 1999)

$$\text{Relative frequency} = \frac{\text{Species frequency}}{\text{Sum of frequency values for all species}} \times 100$$

$$\text{Relative density} = \frac{\text{Number of stems of individual species}}{\text{Number of stems of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Species coverage}}{\text{Sum of coverage values for all species}} \times 100$$

IV= sum of the above three parameters

Year 3:

Make quick walkthrough and photographic record of all sites. Design control procedure for any *P. australis* present.

Year 4:

Repeat procedure for year two on all sites that had to be retreated. Document with photographs. Make quick walkthrough and photographic record of sites that were successfully treated. A repeat of IV data will provide comparative data on success and succession.

Year 5, 7, 9:

Make quick walkthrough and photographic record of sites that were successfully treated. Design control procedure for any *P. australis* present.

Year 6, 8, 10:

Repeat procedure for year four. Document with photographs. Make quick walkthrough and photographic record of sites that were successfully treated. A repeat of IV data will provide comparative data on success and succession.

Table 1.

VIMS Site #	Identification number(s)	approx. size (acre)	observations and field notes	recommended methods
1	yt6.Phraus.a.1	6.03	Down ravine. streams bordering Phrag. Non-tidal	2,1,4
2	yt11.Phraus.b.1	0.06	non-tidal. Very difficult access.	2,1
3	cp2.Ligsin.b.2, cp2.cyndac.b.1	300 m2	*S. alterniflora dominant. Tidal. Possibly smaller than indicated on map, 10 x 3 m size*	2,1,4
4	cp4.Phraus.a.1, cp4.Phraus.b.7, cp4.Phraus.b.6	1	Phrag is on backside of S. cynosuroides marsh. South of parking lot. Tidal. Possibly larger than indicated on map, ~ 1 acre	2,1
5	cp5.Phraus.c.2, cp5.Phraus.c.1, cp4.Phraus.b.2, cp4.Phraus.c.2, cp4.Phraus.b.1, cp4.Ligsin.c.3	2.31	Phrag on backside of S. cynosuroides and alterniflora marsh. Tidal. Located after bridge (going west) on north side of road.	2,1
6	cp5.Phraus.c.3, cp5.Phraus.c.4, cp5.Phraus.b.3, cp4.Phraus.b.5, cp4.Phraus.b.4, cp4.Phraus.b.3, cp5.Longjap.b.11, cp5.Ligsin.c.1	>3 to 5	Phrag located on edges of marsh on south side of road. May be tidal (?). Need to look at aerial photos to see how back Phrag goes. Possibly larger than indicated on map, ~ 5 acres.	2,1,4
7	cp5.Cyndac.b.5, cp5.Cyndac.b.4, cp6.Cyndac.b.5, cp4.Longap.b.8, cp5.Phraus.b.1, cp5.Phraus.b.2.	?	Phrag is growing in the middle of Iva frutescence, Baccharis, and Juniperus and is high up on land behind riprap. Very low density. Larger than indicated on map; Phrag is located in long continuous patch for about 0.25 miles. Access is moderate.	1
8	cp6.Phraus.b.1, cp7.Phraus.b.1	0.72	Phrag fringed by Iva, Juniperus, and Myrica (bay berry). On frontside is Juncus and S. alterniflora. High marsh. Tidal.	2,1
9	cp9.Phraus.b.2	0.5	Phrag on backside of S. alterniflora marsh. Ilex olpaca, water oak, and red oaks on backside of Phrag. Tidal. Possibly larger than indicated on map, ~ 0.5 acres. Use gated, locked side road for access.	2,1
10	cp22.Micvim.c.1	0.02	Non-tidal. Moderate access.	2,1
11	cp26.Phraus.b.1 to b.27, cp26.Phraus.c.1 to c.2, cp27.Phraus.c.1 to c.5., cp26.Ligsin.b.1	~20	Very, very large and extensive patches of Phrag located on both sides of road. Tidal.	3 or 2,4
12	cp30.Phraus.c.5 to c.7, cp30.Phraus.b.2 to b.4.	1.28	Tidal.	2,1
13	cp30.Phraus.c.1 to c.4, cp30.Phraus.b.1, cp30.cyndac.b.1	2.73	Tidal. Cypress trees in marsh.	2,1

14	**cp.31.Phraus.b.1 to b.19, cp31.Phraus.c.1 to c.4, cp31.Cyndac.a1, cp31.Cyndac.c.15, cp31.Cyndac.c.16, cp31.Cyndac.b.10, cp31.Cyndac.b.11, cp31.Lonjap.b.8**	**12**	**Tidal. Very large Phrag area.**	**3 or 2,4**
15	**cp32.Phraus.c.1, cp32.Phraus.b.1, cp32.Phraus.b.2, cp32.Lonjap.b.14, cp32.Lonjap.b.15**	**4.83**	**Tidal. Small, <0.5ac. Confined to small embayment.**	**2,1**
16	**cp34.Phraus.c.1 (no PhrAus)**		**Phrag patch on other northwest side of Powhatan Creek bridge. On both COLO and private property.**	**2,1**
17	**jt2.Phraus.a.3, jt2.Phraus.b.1, cp34.Phraus.b.1 jt2.Phraus.x.1 (jt2.Phraus.a.1, jt2.Phraus.a.2, jt2.Phraus.a.5)**	**< 5**	***Many large patches surrounded by S. cynosuroides. Possibly larger than indicated on map, > 5 acres. Tidal.***	**2,1,4**
18	**Jt2.Phraus.a.4, jt2.Phraus.c.1**	**0.34**	**Phrag on both side of cypress interfluvial. Tidal. Two patches, one large >2ac. And one small <0.5ac.**	**2,1**
19	**jt3.pautom.a.3**	**0.02**	**fringe-tidal marsh**	**2,1**
20	**jt3.Phraus.a.1**	**0.5**	**Tidal. Off side of road. Possibly larger than indicated on map, ~ 0.5 acre.**	**2,1**
21	**jt3.Phraus.a.2**	**0.15**	**extremely tough to get to. Larger than original report.**	
22	**jt3.Phraus.b.1**	**0.1**	**Tidal. Possibly slightly larger than indicated on map, ~ 0.1 acre.**	**2,1**
23	**jt4.Phraus.a.3**	**0.2**	**Tidal. Far edge of Passmore Creek, extremely difficult access. Larger than indicated.**	**2,1**
24	**jt4.Phraus.b.1, jt4.Phraus.a.1, jt4.Phraus.b.2, jt4.Phraus.a.2**	**0.5**	**Phrag surrounded by S. cynosuroides. Possibly larger than indicated on map, ~ 0.5 acres.**	**2,1**
25	**jt1.Phraus.b.3.**	**0.25 - 0.5**	**Phrag fringes loblolly pine tree grove. Tidal. Possibly larger than indicated on map, ~0.25 to 0.5 acre.**	**2,1**
26	**jt1.Phraus.b.1, jt1.Phraus.b.2**	**1**	**Crescent shaped patch and another long patch along other side of water. Tidal. Size ~ 1 acre. Located almost at end of point of land.**	**2,1**

Methods Code	
1	**wicking**
2	**hand spraying**
3	**aerial spray**
4	**burn**

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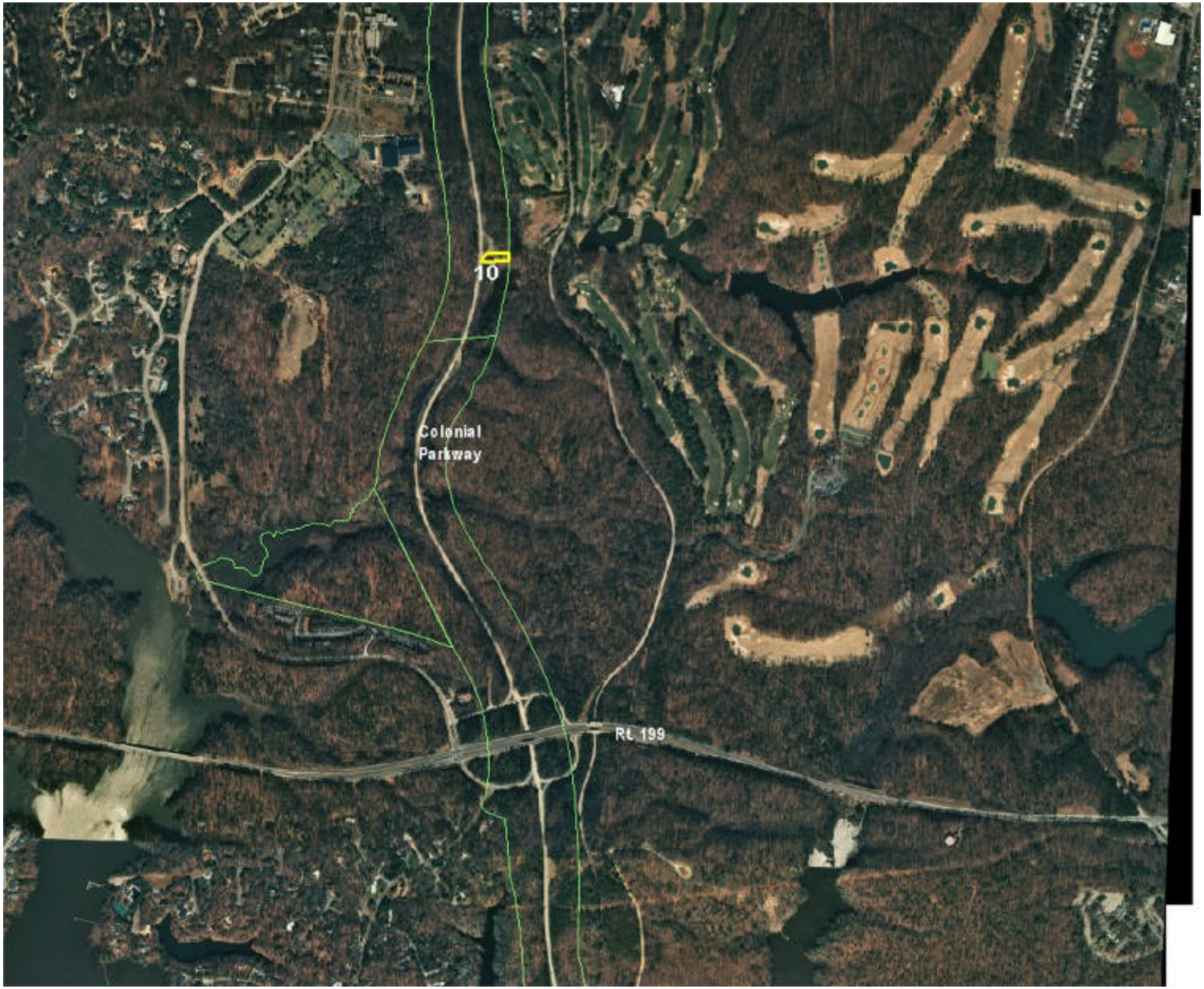
Jamestown Island and Environs

College Creek



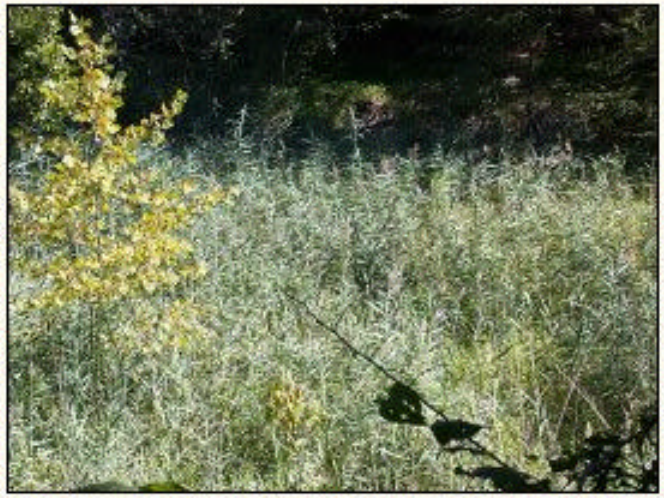
Great Oak

Felgates Creek to Indian Field Creek

Yorktown
Battlefield

Phragmites of Colonial NHP, September 2002

Phrag_site01-a.jpg



Phrag_site01b.jpg

Phrag_site02-a.jpg

Phrag_site02-b.jpg

Phrag_site03-a.jpg

Phrag_site03-b.jpg

Phrag_site03-c.jpg

Phrag_site03-d.jpg

Phrag_site04-b.jpg

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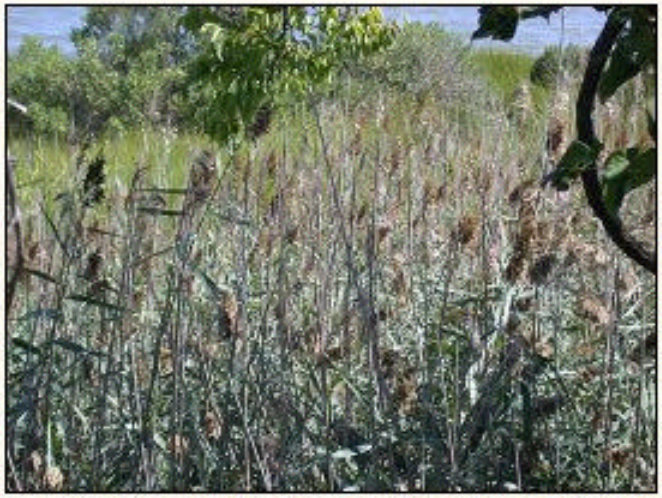

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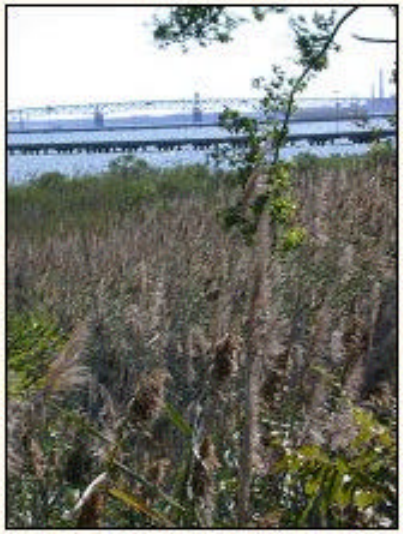
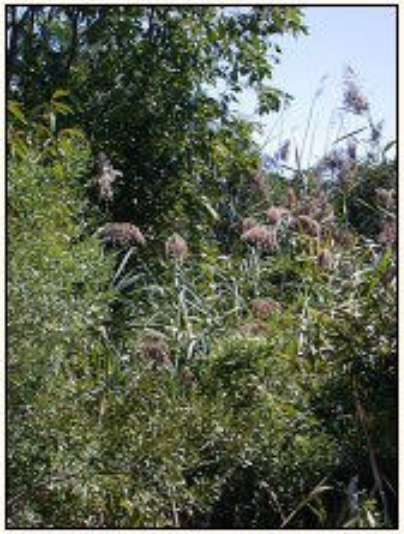


Phrag_site05-c.jpg

Phrag_site06-c.jpg

Phrag_site07-a.jpg

Phrag_site07-b.jpg



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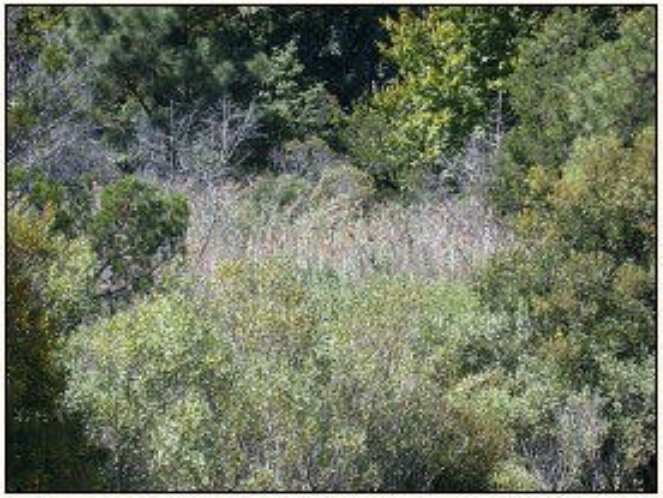

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Phrag_site08-b.jpg

Phrag_site09-b.jpg

Phrag_site1-a.jpg

Phrag_site10-a.jpg

Phrag_site10-b.jpg

Phrag_site10-c.jpg

Phrag_site11-a.jpg

Phrag_site11-b.jpg

Phrag_site11-c.jpg

Phrag_site11-d.jpg

Phrag_site11-e.jpg

Phrag_site12-a.jpg

Phrag_site12-b.jpg

Phrag_site13-a.jpg

Phrag_site13-b.jpg

Phrag_site13-c.jpg

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Phrag_site14-b.jpg

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Phrag_site14-d.jpg

Phrag_site14-e.jpg

Phrag_site14-f.jpg

Phrag_site16-a.jpg

Phrag_site16-add.jpg

Phrag_site16-b.jpg

Phrag_site16-c.jpg

Phrag_site16-d.jpg

Phrag_site17-a.jpg

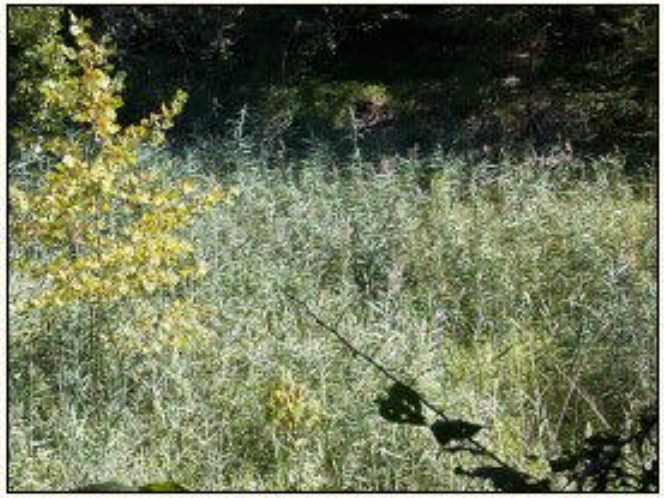
Phrag_site17-b.jpg

Phrag_site18-a.jpg

Phrag_site18-b.jpg

Phragmites of Colonial NHP, September 2002

Phrag_site18-c.jpg



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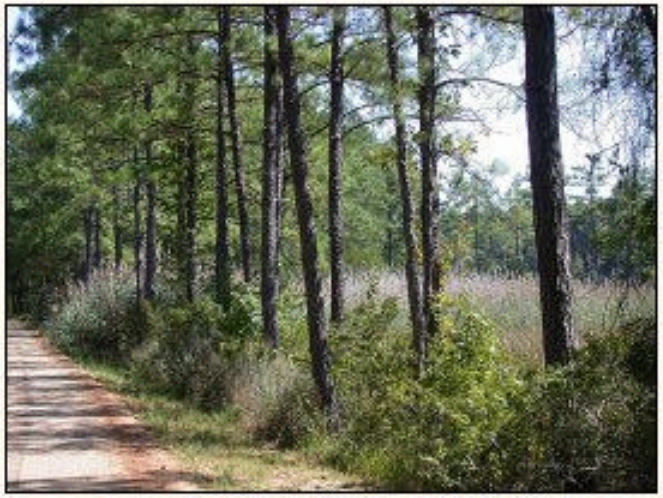
Phrag_site2-b.jpg



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Phrag_site24-a.jpg

Phrag_site24-b.jpg

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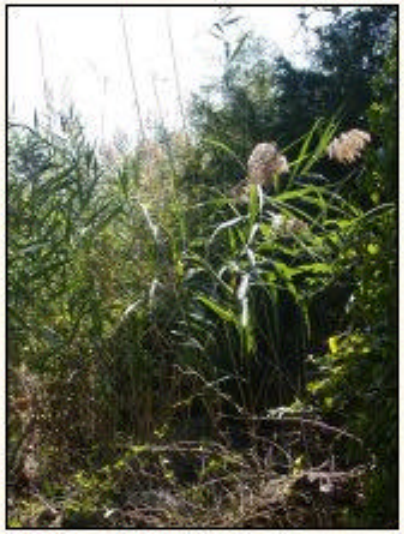
Phrag_site3-b.jpg

Phrag_site3-c.jpg

Phrag_site3-d.jpg

Phrag_site4-b.jpg



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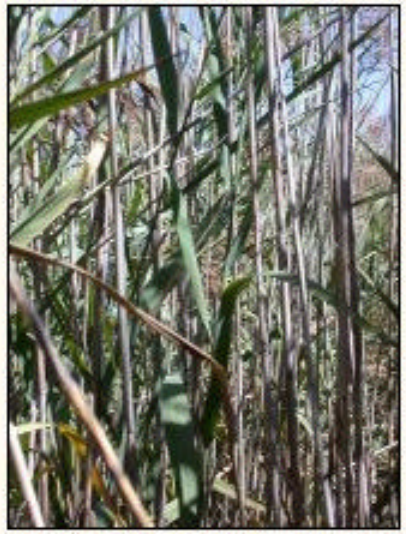

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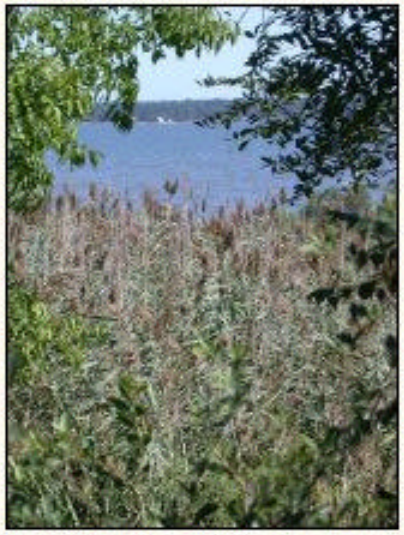

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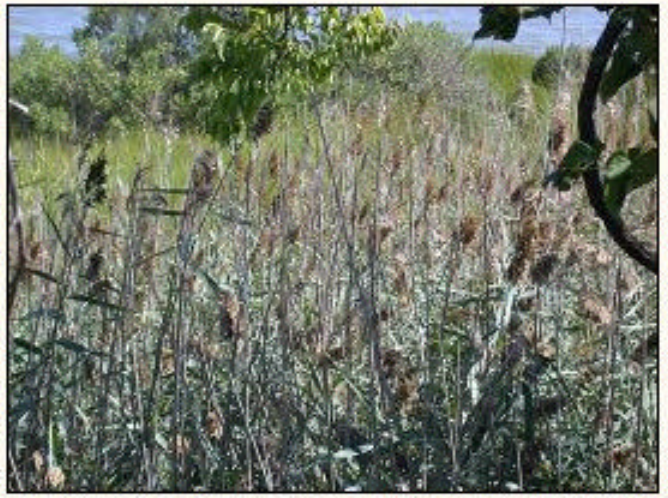

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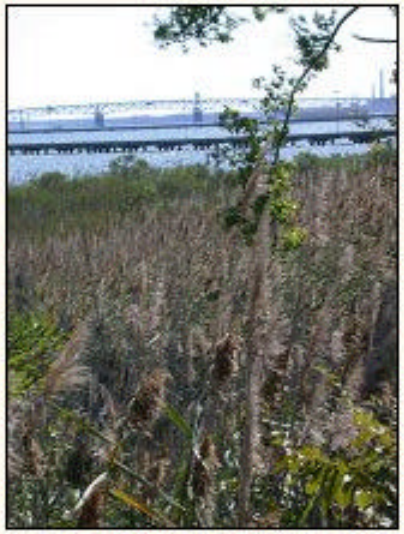

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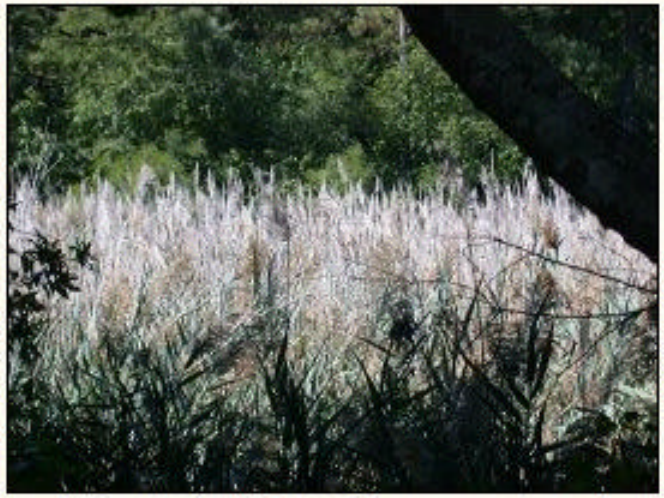

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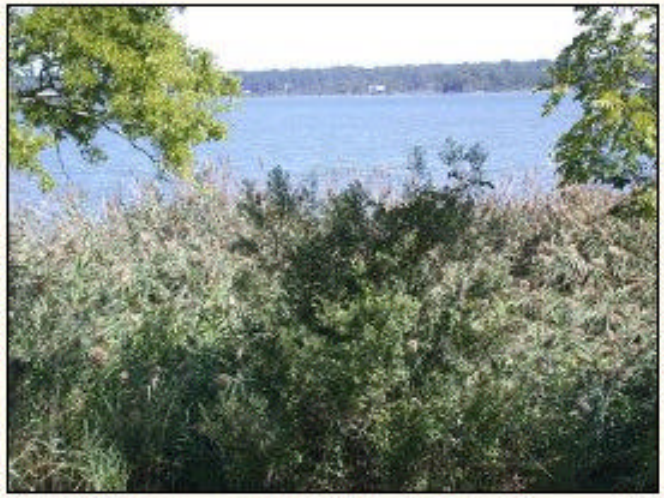

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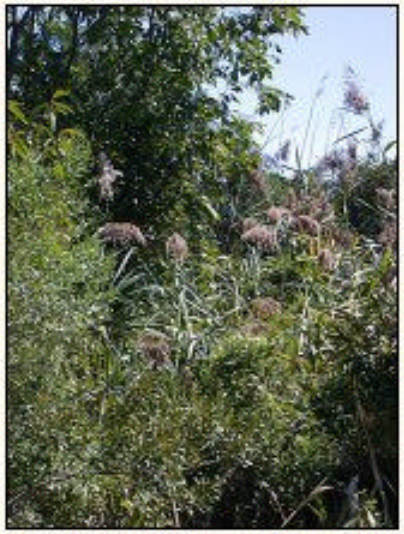

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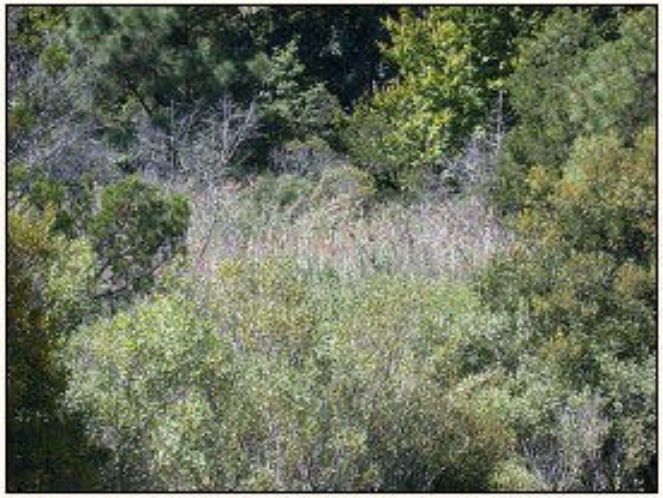

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Phrag_site8-b.jpg

Phrag_site9-b.jpg